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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

TREE INJECTION STUDIES

With Lodgepole Pine and Notes on
Western White Pine

by

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the trees were dominants, 22.8% codominants and 5.3% intermediates. The crown length averaged 31 feet and the height of the first living limb was 22.3 feet.

Notes were taken on each tree as to insect attack, blue stain development, condition of the phloem and foliage at the time of injection, and what the subsequent effect of the poison was on each. The trees were found to be infested from the ground to an average height of 29.5 feet. The degree of attack is represented by the following percentages: 47.5% heavy, 17.6% medium, and 34.9% light. The primary bark beetle found infesting them was the mountain pine beetle, *Dendroctonus monticolae* Hopk. Associated with this beetle were several secondary ones, such as *Ips oregoni* Eich., *Pityogenes knechteli* Sw., *Pityophthorus burkei* Blackman, certain predators, parasites, etc.

Most of the injected trees were just being attacked when the poisonous solutions were applied to them. This varied from the parent adult galleries being only begun to fully extended and eggs laid. In some instances it was observed that attacks continued after treatment, in others that the beetles left partly constructed parent tunnels prematurely following injection. In some cases tiny larvae and small streaks of blue stain were found at the time of the fall examinations, two to six weeks after treatment.

Treatment

Between July 22 and October 2, 1930, two hundred eleven infested lodgepole pine trees were treated by being injected with poisonous solutions containing a dye. One hundred eighty-one of them were poisoned during the period July 22 to August 21. Following this, six additional infested trees

and four normal ones were injected with only a dye solution, which were to serve as checks in determining the importance of poison and insects in affecting distribution of the materials. The remaining thirty-three trees were treated in September and October.

The infested trees, treated with initial heavy dosages of poison, were injected between July 22 to 30th, inclusive. Those injected with light dosages in larger quantities of water were treated between July 31 and August 8th. The treatments were made as follows:

1. <u>Sodium arsenite</u>, 55 trees

7 trees, 2 ounces to 2 quarts of water
12 " 4 " " " " " "
7 " 6 " " " " " "
5 " 8 " " " " " "
4 " 1/2 ounce to 10 " " "
4 " 1/2 " " 2 " " "
8 " 1 " " 10 " " "
4 " 1 " " 2 " " "
4 " 3 ounces " 10 " " "

2. <u>Zinc chloride</u>, 20 trees

1 tree, 5 ounces to 2 quarts of water
11 trees, 10 ounces to 2 quarts of water
4 " 15 " " " " " "
4 " 1/2 ounce " 10 " " "

3. <u>Sodium fluoride</u>, 15 trees

1 tree, 1 ounce to 2 quarts of water
1 " 3 ounces " " " " "
4 trees 5 " " " " " "
2 " 6 " " " " " "
1 tree, 7 1/2 " " " " " "
4 trees, 1/2 ounce " 10 " " "
2 " 1 " " 10 " " "

4. Copper sulphate, 37 trees

5 trees, 5 ounces to 2 quarts of water
6 " 10 " " " " " "
5 " 16 " " " " " "
6 " 20 " " " " " "
5 " 2 " " 10 " " "
5 " 5 " " 10 " " "
5 " 10 " " 10 " " "

5. Potassium cyanide, 54 trees

5 trees, 3 ounces to 2 quarts of water
1 tree, 4½ " " " " " "
6 trees, 6 " " " " " "
13 " 10 " " " " " "
1 tree, 12 " " " " " "
7 trees, ½ ounce " 10 " " "
3 " ½ " " 2 " " "
3 " 1 " " 10 " " "
2 " 1 " " 2 " " "
11 " 2 ounces " 10 " " "

The infested trees treated with only a dye solution were injected on August 8 as follows:

3 trees, ½ gram of light green in 2 quarts of water
3 " " " " " " " 10 " " "

The normal trees were injected between August 5 and 10, as follows:

4 tree, ½ gram of light green in 2 quarts of water.

In order to determine if any difference existed as to the rates of absorption and distribution of poisonous solutions, between trees injected in the summer (July-August) and those injected in the fall, Gibson treated thirty-three additional infested lodgepole pine trees during September and October. Those poisoned on September 8 and 9 are as follows:

1. Sodium arsenite, 8 trees

1	tree,	2	ounces	to	2	quarts	of	water
1	" ,	"	"	"	4	"	"	"
1	" ,	"	"	"	8	"	"	"
1	" ,	"	"	"	10	"	"	"
1	" ,	4	"	"	2	"	"	"
1	" ,	4	"	"	4	"	"	"
1	" ,	"	"	"	8	"	"	"
1	" ,	"	"	"	10	"	"	"

2. Sodium fluoride, 5 trees

1	tree,	2	ounces	to	2	quarts	of	water
1	" ,	"	"	"	4	"	"	"
1	" ,	4	"	"	2	"	"	"
1	" ,	"	"	"	4	"	"	"
1	" ,	"	"	"	8	"	"	"

3. Potassium cyanide, 10 trees

1	tree,	2	ounces	to	1	quart	of	water
1	" ,	"	"	"	2	quarts	of	water
1	" ,	"	"	"	4	"	"	"
1	" ,	"	"	"	8	"	"	"
1	" ,	"	"	"	10	"	"	"
2	trees,	4	"	"	2	"	"	"
1	tree,	"	"	"	4	"	"	"
1	"	"	"	"	8	"	"	"
1	"	"	"	"	10	"	"	"

These trees poisoned on October 2 are as follows:

1. Sodium arsenite, 2 trees,

   Each with 3 ounces to 2 quarts of water

2. Zinc chloride, 2 trees,

   Each with 4 ounces to 2 quarts of water

3. Sodium fluoride, 2 trees,

   Each with 3 ounces to 2 quarts of water

4. Copper sulphate, 2 trees,

   Each with 10 ounces to 2 quarts of water

5. Potassium cyanide, 2 trees,

   Each with 6 ounces to 2 quarts of water

1. <u>Sodium arsenite</u>, 8 trees

1 tree,	2	ounces	to	2	quarts	of	water
1 " ,	"	"	"	4	"	"	"
1 " ,	"	"	"	8	"	"	"
1 " ,	"	"	"	10	"	"	"
1 " ,	4	"	"	2	"	"	"
1 " ,	4	"	"	4	"	"	"
1 " ,	"	"	"	8	"	"	"
1 " ,	"	"	"	10	"	"	"

2. <u>Sodium fluoride</u>, 5 trees

1 tree,	2	ounces	to	2	quarts	of	water
1 " ,	"	"	"	4	"	"	"
1 " ,	4	"	"	2	"	"	"
1 " ,	"	"	"	4	"	"	"
1 " ,	"	"	"	8	"	"	"

3. <u>Potassium cyanide</u>, 10 trees

1 tree,	2	ounces	to	1	quart	of	water
1 " ,	"	"	"	2	quarts	of	water
1 " ,	"	"	"	4	"	"	"
1 " ,	"	"	"	8	"	"	"
1 " ,	"	"	"	10	"	"	"
2 trees,	4	"	"	2	"	"	"
1 tree,	"	"	"	4	"	"	"
1 "	"	"	"	8	"	"	"
1 "	"	"	"	10	"	"	"

Those trees poisoned on October 2 are as follows:

1. <u>Sodium arsenite</u>, 2 trees,

   Each with 3 ounces to 2 quarts of water

2. <u>Zinc chloride</u>, 2 trees,

   Each with 4 ounces to 2 quarts of water

3. <u>Sodium fluoride</u>, 2 trees,

   Each with 3 ounces to 2 quarts of water

4. <u>Copper sulphate</u>, 2 trees,

   Each with 10 ounces to 2 quarts of water

5. <u>Potassium cyanide</u>, 2 trees,

   Each with 6 ounces to 2 quarts of water

Discussion of Data

The trees were divided into three groups for final examination to note if there were any differences as to distribution of poison due to length of time it remained in the stem. In all previous injection work with lodgepole pine a period of several months elapsed following treatment, before noting results.

The examination of group one, comprising eighty-nine trees, was made within three weeks of the time of treatment, between July 31 and August 8. The six infested and four normal trees injected with only a dye solution were examined on August 12. The examination of group two, comprising thirty-four trees, was made by Mr. Gibson within six weeks of the time of treatment, on September 5 and 6. The examination of the third group of fifty-five trees will not be made until nine months after treatment, in June, 1931. At this time the additional thirty-three trees injected during the fall of 1930 will also be examined.

1. Injection of Poison in Infested Trees, Group I

The data pertaining to the 89 trees in group one are presented in Table I.

In regards to absorption, it will be noted that this period averaged about one day where trees were injected with only two quarts of solution. The copper sulphate solution was absorbed most rapidly, it being taken up in from one and one-half to eighteen hours'time. This period extended to several days where trees were injected with ten quarts of solution, regardless of the kind or dosage of poison used. In some instances it was not all

taken up by the time the tree was felled. Sometimes pitch was found in the cut; at others, globules were observed floating on top of the solution, in which case it was apt to be milky white in color. This suggested that considerable pitch might be present in the tree and may have prevented the solution from being taken up through the stem.

As to distribution, it will be noted that in general the results were quite variable and that in no case had the poison penetrated the entire stem within three weeks after the time of injection. Only in three instances, in copper sulphate trees, did the solution reach the top and in these it was present only in streaks. The indicator was seldom found in the outer rings for any considerable distance along the stem. It appeared to pass quickly to the inner ones.

It was noted above that after July 31 most of the trees contained additional quantities of water in weaker dosages of poison. They were to serve as checks to determine whether or not dosage influenced conduction. Reference to Table I indicates that in a few instances the lighter dosages of poison in additional quantities of water were taken further up the stem. However, at the same time, it appeared to decrease the lethal area.

In general, the poison had an immediate greater lethal effect on the phloem than it did on insects. In several of the trees the former was killed to a much greater height than the latter. The indicator was taken up the stem in streaks, often above the infested length, but the insects were killed only in a relatively small portion of this area. Under the most favorable conditions there were only a very small percentage of the trees with much of the brood killed at the time of this examination. In only two instances, where there were light attacks which extended up the stem

less than the average infested length, were there complete mortality. These consisted of one sodium arsenite and one potassium cyanide tree, each of which had been injected with two quarts of solution. In three other trees, one injected with sodium arsenite, one with sodium fluoride, and one with potassium cyanide, the broods were killed over two-thirds their infested length. In the other trees, the beetles were killed only a few feet all around the stem and in streaks just a short distance above this.

The kind of poison or dosage used did not appear to be of much importance in the treatment of these trees, as far as the immediate effect on insects was concerned. The foliage, however, was slightly affected by the following chemicals: sodium arsenite, zinc chloride, and sodium fluoride. Sodium arsenite caused the fading of foliage of five trees, or 21.8% of those examined that were injected with this chemical. In these trees the lower halves of the crowns were the part first affected. The upper halves, except in one instance, appeared normal at the time. It is of interest to note that the arsenic trees began to die in the opposite manner from which ordinary beetle-attacked ones do, that is, from the base to the top of the crown. The 1929 needles were affected before those of 1930, the former showing most discoloration. This is in accordance with observations on trees previously treated with this poison.

In the case of the other two poisons, four trees were affected and in the same way as unpoisoned infested ones, that is, from the top to the base of the crown. The tops of these trees were sorrel in color, while the bases were still green.

In accounting for the lack of distribution of poisons in sufficient quantities to kill the beetles, several possibilities were suggestive at this time, among which were the following: (1) dosage of sufficient strength to result in killing cells of the wood, thereby interferring with processes of conduction; (2) pitch partially filling the kerf, and (3) the lack of sufficient activity in the trees in this particular locality at this season to absorb enough poison to kill the beetles within three weeks' time.

It has already been pointed out that the reduction of the dosage of poison and addition of water did not materially affect distribution. It was noted, however, in several of the above trees that pitch was present, either in the cut or in globules in the solution, often causing it to have a clouded appearance. Because of this, it was thought that pitch might have been at least a contributing factor for the lack of distribution of poison. In addition to this, the time element was believed to be of some importance in this respect, a discussion of which is given later in this report.

2. Injection of a Dye in Infested Trees

Because of the inconclusive results obtained from the examination of the infested trees mentioned above that were injected with poisonous solutions, it was thought advisable to determine what the distribution would be in such trees when an aqueous only stained with light green was introduced. Accordingly, on August 8, six infested pines containing parent adults and eggs were treated as noted above. An examination of them four days after injection indicated that the dye solution was not being absorbed any faster than the average poisoned tree and not nearly as rapidly as those injected with copper sulphate. Besides, it

was noted that the light green dye was not coming in contact with many of the parent adult egg galleries. In several instances it was found to be not within ¼ to ½ inch of each side of most of them. At times the non-stained area extended to the depth of one or two annual rings. Below this the indicator was usually present. This suggested that possibly the drying of the phloem might be affecting the distribution of poisons. That such a drying does occur in beetle-attacked areas was demonstrated in shortleaf pines infested with the southern pine beetle, in experiments conducted at Asheville, N.C., during the season 1930.

The data pertaining to distribution of the dye are presented in Table II.

It will be seen that the results do not vary much from the trees injected with poisons, and that there is also some suggestion here that mechanical difficulties were partially responsible for this. This would explain the uniformly poor results obtained in the use of various poisons and with different dosages.

3. Injection of a Dye in Normal Trees

Noting the relatively poor results in the distribution of a non-toxic dye, like light green in recently attacked trees, it was decided to try to determine the importance of beetle work in this connection. Therefore, on August 10th four normal trees were injected with an aqueous solution of light green to serve as checks on the above attacked trees similarly treated. Two of the four trees chosen (1453 and 1462) were located along the bank of a stream, so that it was certain that their roots had access to plenty of

water. The other two trees (1463 and 1464) selected were located on a hillside not very far away. The results are presented in Table III.

It was soon noted in one tree (1453) that only a very small amount of solution was being absorbed and that it was being taken up only on one side of the stem, three days after injection. This made it necessary to reinject the other side of the trunk. Then the solution went up this side in streaks to within eleven feet of the top. In the other three normal trees, distribution was likewise poor. Indications were that mechanical difficulties were partly responsible, due to the presence of a certain amount of pitch in the kerf. The presence of water near two of the trees did not appear to aid in the distribution of the dye, and in this respect confirmed findings in the earlier part of the paper in regard to the effect on injecting trees with additional quantities of water that were added to the initial dosages.

In considering all trees injected up to this time, it appears that factors other than the clogging of the kerf with pitch were responsible for the lack of distribution of poisonous solutions in these trees, since many of them whose kerf was clear and that had absorbed the liquid in a relatively short time, did not have a good distribution of poison throughout their stems.

It is possible that the trees might have a high pitch content which could interfere with distribution. There is also the possibility that insufficient activity in the trees at this season prevented the absorption of

sufficient quantities of poison to kill the beetles very far up the stem within such a short period of time as three weeks after injection.

PART II

Notes on Injection of Western White Pines

Since the results obtained from the injection of lodgepole pines were so variable, it was thought advisible to try to determine how much of this was due to the species of tree. It has been noted that the lodgepole pine trees made slow growth and it has further been suggested that they might have a high pitch content which possibly influenced the degree and rate of distribution of poisonous solutions throughout the tree. In regards to white pine, it was thought that the pitch content might be considerably lower than that of lodgepole pine, and if so, and providing the above contension is true in regards to it, then there should be a more thorough distribution of poisonous solutions in these trees. To test this, six western white pines were selected for treatment. They averaged 15.8 inches DBH and 131.7 feet high. The width of the last ten rings averaged 5/16 of an inch and there were 16.7 rings to the last half inch of wood. A comparison of the rate of growth of these with the average lodgepole pine will show that in white pine the growth was somewhat faster. The trees were infested from 15 inches to an average height of 112 feet, or to within a top diameter of 5.6 inches. They were injected between August 17 and 21 and examined on September 25, nearly five weeks later. These data are presented in Table IV.

It will be noted that, with two exceptions the absorptive time averaged about two days and that there was a somewhat better distribution of poisons in these trees than in the lodgepole pines. While the mortality of the brood in some of the trees was not as high as expected, yet the indications were that the distribution of poisons and dyes was much more successful. In one case, a sodium arsenate tree, practically a 100% mortality of the parent adults occurred and in addition all the brood were killed as eggs. In this species of tree; it meant that distribution was almost complete throughout the entire stem. As only one tree was treated with this poison, it is not possible to say what the effect would have been on a series of trees. However, it is believed that it should be tested further to note its possibilities.

One normal tree was selected for injection with an aqueous solution of light green. The liquid was absorbed in two days' time. An examination of this tree thirty-five days later revealed that the indicator was present in the outer two rings for a distance of eighty feet, about three-fourths the length of the tree. This compared more faverably with the poisoned white pine trees than what the normal lodgepole pines did with the poisoned ones.

Although there is not enough data to warrant drawing any conclusions, it is possible that the variation in distribution of solutions in these two species of pines might have been due to a difference in pitch content, as well as to a somewhat greater length of time following injection before the trees were examined.

Examination of Poisoned Infested Lodgepole Pines

Comprising Group II

An examination of the thirty-five poisoned, infested lodgepole pines, comprising group two, was made on September 5 and 8, between five and six weeks after treatment. The data are presented in Table V.

Considering the distribution of poison in the twelve sodium arsenite trees first, it will be seen at once that there is a striking difference in results between these trees and those in group one, in that the poison has penetrated practically the entire length of the trees and has had a marked effect upon the brood, phloem and foliage. This difference is apparently due to a greater length of time in which the poison has had to reach the upper parts of the stem, since those trees treated in a like manner and at the same time, and examined within three weeks' time after injection (Table I) showed no such degree of control. It will be noted (Table V) that although some of the parent adults were not affected, the brood were killed all around the stem as eggs or tiny larvae along the entire infested length in 50% of the trees. In the remaining ones the poison was nearly as effective since the rbood was killed all around the stem from one-half to two-thirds the infested length and in streaks the remaining distance. It is doubtful if even a small brood could have developed successfully in such trees. Thus, there was a very high mortality of brood in all of the successfully injected arsenic trees which were examined in group two. The phloem also was killed along the entire stem in most of these trees and the foliage of all was affected. In one instance the entire crown had turned red but in the majority of them the lower half was this color while the upper was just beginning to fade. The addition of water, or increased

dosage did not materially affect the results obtained.

The failure of four zinc chloride trees may be attributed to mechanical difficulties, since pitch and sediment stopped up the tubes or kerfs to such an extent that the poison was not as effective as in the trees in group one, examined only three weeks after attack.

The one sodium fluoride tree examined is of signigicance because the low dosage of one-half ounce was as effective six weeks after treatment as much higher ones were within three weeks of the time of injection.

The six copper sulphate trees exhibited a marked increase in the amount of the phloem killed as compared to those of group one. The effect on the brood was not as striking as on the phloem, but there was indicated a slightly higher mortality over the trees in groupnone. The tops of only two trees were observed to be fading.

Eleven trees were treated with potassium cyanide in group two. In those trees with low dosages, to which additional quantities of water had been added, the lethal effect was greatly lessened and the mortaility was not any more effective than those similarly treated in group one. However, in those trees with stronger dosages, complete kills were obtained in one-third of those treated and in the rest they had a greater lethal area than in those examined previously. The phloem was killed over a proportionately larger area also. The foliage on the top of only one tree had faded, this one had turned red.

An examination of the remaining trees, constituting group three, and those treated during September and October, as well as the additional studies proposed for June, 1931, should aid in determining the relative

importance of pitch and time as factors in the distribution of poisonous solutions in lodgepole and western white pines.

General Conclusions

Preliminary results obtained from an examination of the first two of three groups of infested and normal lodgepole pine trees, injected with poisons and dyes by the saw-kerf method, suggest the following conclusions:

1. The distribution of poisons throughout the stem of infested trees in sufficient quantities to have alethal effect upon barkbeetles, appears to require different lengths of time according to tree species. Thus poisons, which were entirely effective in shortleaf pines shortly after injection, when applied in a similar manner to lodgepole pines they were found to be only slightly effective. However, when the latter were examinaed after a longer interval of time, the results were much more satisfactory. Indications were that similar injections of poison in western white pine might be more effective in a given period than in the case of lodgepole pine.

2. It is suggested that this difference in distribution may be partly due to a variation in the pitch content of various tree species.

3. Pitch probably acted as a mechanical barrier in several instances, since quite a few infested trees injected with poisons, as well as other infested and normal ones injected with only dyes, had a relatively poor distribution of poison.

4. The lethal area apparently is not influenced by dosage as much as it is by conditions favoring distribution. A low dosage of poison under favorable conditions apparently is more effective over a much greater area than higher ones, where conditions are not as favorable.

5. The addition of water to the initial application of poisons did not have a material effect upon distribution. In some instances the poison appeared to be carried slightly further up the stem, but it also had the tendency to decrease its lethal effect, especially upon the beetles.

6. The killing of the phloem for a considerable distance above the indicator in several instances, supports previous findings, in that certain dyes are only relative indicators of the path of poisons in injected trees.

7. The phloem of the tree appears to be more readily affected by poisons than the insects.

8. In future tests, it is suggested that the relative importance of pitch, as well as the length of time the poisons are allowed to remain in the tree before examination, be given special attention. The use of a pitch solvant, such as wood alcohol, should aid in determining factors important in the distribution of poisons in the trees. It is suggested that in subsequent tests only the poison, sodium arsenate be used. It is cheap, easily obtained and readily handled.

9. Finally, until more research work is done to obtain additional information concerning the factors influencing the distribution of poisons in lodgepole and western white pines, the control of barkbeetles by the saw-kerf method of injection is not practical.

TREE INJECTION STUDIES WITH LODGEPOLE PINE, AND NOTES ON INJECTION OF WESTERN WHITE PINE

Tree injection studies with lodgepole pine during 1930 were conducted in the Beaverhead National Forest at the Battlefield by the writers, assisted by H. J. Rust and two nontechnical men. The work with western white pine was performed in the Kaniksu National Forest along Pass Creek, in the vicinity of Sullivan Lake, by R. A. St. George and Donald DeLeon.

Purpose

The purpose of the experiment was to note if the poisoning of trees by the saw-kerf method of injection was a practical means of controlling western pine barkbeetles.

Preliminary results obtained from experimental tests conducted at Asheville, N.C., during the year 1929, in connection with shortleaf pine infested with the southern pine beetle, were quite conclusive. In these tests it was determined that several chemicals were effective in killing broods of barkbeetles along the entire stem within a short time after injection, when poisons were introduced into the sapstream of freshly attacked trees.

In the studies concerned with the injection of infested lodgepole pine, the initial dosages used were rather large ones. This was done for two reasons. First, because it was thought that such a procedure would yield immediate results, thus making it possible to quickly reduce the dosages until a lethal limit was reached for each chemical. Second, because

the trees used were much bigger ones than those treated hitherto, which necessitated using a considerably larger quantity of poison to cover the increased area of bark surface.

Method

The saw-kerf method of injection was used. This method was described in the 1929 report on injection studies that were conducted at Asheville, N.C. A change in technique was made relating to the type of band used to hold the solution in the kerf until absorbed by the tree. Instead of using a piece of rubber innertubing for this purpose, two other materials were tried. One was a mixture of grafting wax, the other a tin collar. The grafting wax consisted of a mixture of four parts mutton tallow to six parts each of rosin and beeswax. This formula was found to be satisfactory for use in injecting trees in the vicinity of Washington, D.C. and Asheville, N.C., where the range in temperature in pine stands during the summer months was not greater than 45° F. (50°-95°). The chief advantage in the use of grafting wax was that it could be applied easily to the trunks of irregularly shaped trees, which are frequently encountered in lodgepole pine stands. After injecting eighty-one trees by this method, it was apparent that grafting wax was impractical to use as a band in this locality. It had the disadvantage of being affected by extremes in temperature that were experienced on high ridges at an elevation of 6,500 feet, near the top of the continental divide. This range was as much as 60° F. (35°-95°) on some days, or 15° in excess of that in the region for which it was tested and found effective. Only a few degrees above or below the tested limits made a marked difference on the composition of the material

and its usefulness for the purpose for which it was intended.

The collar* (the second type of band that was tried) consisted of a

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* This collar was perfected by Mr. Rust. It was developed from different types of paper and composition collars that were devised by Mr. Gibson and other members of the Coeur d'Alene station in previous injection studies.

---

sheet of tin that had a smaller diameter at the base than at the top, causing the latter to flare out when the former edge was fastened by being tacked to the tree. Along one side an S-shaped flange made a tight connection possible. For very large trees it was found possible to attach one sheet of tin to another by means of the flange, making it possible to use them on any tree regardless of its diameter. In order to prevent leakage along the seam and around the lower tacked edge,a thin layer of cup grease, the consistency of "zeroline", was used. Another advantage in the use of this collar was that it is not subject to being affected by extremes in temperature. It was also found to be adaptable to trees with irregular shaped trunks. Tin collars were used on one hundred and forty trees.

Part I

Injection of Lodgepole Pine

The trees used in this study were selected from a fairly even-aged stand of lodgepole pine. They were located within a ravine and extended to the tops of ridges on both sides. These trees averaged 11 inches DBH and 64.6 feet high. The width of the last 10 rings was 1/4 inch and there were 20 rings to the last half inch of wood. According to crown class, 71.9% of

TABLE I

INJECTION OF LODGEPOLE PINE TREES INFESTED BY THE MOUNTAIN PINE BEETLE (Group I)

Tree Number	Solution	Amts.	Absor. Time	Cond. of Kerf.	Days Treat. - Final Ex.	Distribution of Indicator	Effect on Brood	Effect on Phloem
1383	Sodium Arsenite Water to	2oz 2 qts	4 das	Pitch globules	8	bg considerable ag in streaks to 3 feet	bg partial kill ag kill where poison	Dead in streaks to 4 ft. ag.
1384	" " " "	" "	2 das	Undet.	7	bg in streaks ag in streaks to 6 feet	bg alive ag killed in streaks to 3'	Dead in streaks to 6 ft. ag.
1389	" " " "	" "	2 "	"	7	ag to 1 ft.	bg 25% kill ag kill to 1 ft.	Dead where poison
1302	" " " "	4 oz. 2 qts	1 "	"	6	ag in streaks to 12 ft.; in outer rings 1'strip to 6 feet.	bg 75% kill ag kill in 1' strip to 6'	
1511	" " " "	" " " "	1 "	"	13	ag up outer rings to 10'; one streak to 65'; in 7th and 8th rings.	bg alive ag killed to 3'-alive above	
1337	" " " "	" " " "	1 "		11	ag up outer rings to 4', above in streaks to 15', where not in outer 20rings	bg 80% kill ag 100% kill to 4';alive above except few streaks	bg dead where poison ag dry in streaks to 20 feet.
1338	" " " "	" " " "	1 "		11	Mostly in stump in outer 17 rings; ag to 6';in streaks to 18'	bg 100% kill ag where poison	Dead where poison
1339	" " " "	" " " "	1 "			ag in streaks to 18 ft.	bg living larvae ag dead in streaks to 4'	bg dead ag dead full length
1340	" " " "	" " " "			14	ag none bg all	bg larvae dead ag adults and larvae alive	In wedges ag - some in top
1341	" " " "	" " " "	(Sediment in can)		13	ag to 20' - in streaks to 30 feet.	bg 50% kill ag in streaks to 4 ft.	Dead where poison

Continued

1343	Sodium arsenite Water to	6 oz. 2qts	(Partly absorbed in 12 das)		13	In streaks to 30' where present in 10th - 20th rings.	bg) ag) little effected	bg dead ag dead to 15' and in streaks to 20'
1322	" "	6 oz 2 qts	Leakage	Undet.	12	In streaks ½ around to 38' ag.	ag killed to 15'	Dead where poison
1364	" "	" "	1 da.	"	13	ag to 4'; in streaks to 15'	bg killed in streaks ag killed where poison	Dead entire stem
1313	Sodium arsenite Water to	8 oz 2 qts		"	9	ag up outer ring to 1½ ft. tapering to 3 inches.	bg 75% kill ag kill to 1½', alive above	
1314	" "	" "	Leakage	"	10	bg 2/3around to ground ag " " to 2'; in streak to 10'	Killed where poison	Dead where poison
1318	" "	" "		"		1/2 around to 3' ag	" " "	
1402	" "	½ oz. 10qts	10das 2 qts left when felled	"	10	Up all around to 10' ag, in streaks to 21 feet.	bg alive ag kill 1/2 around to 10'	Dead in streaks to 10' ag.
1408	" "	¾ oz 2qts	1 da.	"	6	Up all around 2' ag; in streaks to 12' ag.	ag kill to 2 feet	
1393	" "	1 oz 10qts	6 "	"	11		bg alive ag kill half around to 3'	Dead to 15', and bg streaked 15'-40' ag
1394	" "	" "	11 das 2 qts left when felled	"	11		bg complete kill ag kill in streaks to 4'	Dead to 26' ag; in streaks to 44' ag.
1410	" "	1 oz 2qts	1 day	"	6	bg only to 4 inches ag up to 8', in streaks to 12'	bg) ag) alive	Dead where poison
1422	" "	3 oz 10qts	7 "	"	10	In streaks to 40' ag	bg alive ag kill to 6'; in streaks to 15'	Dead to 40', in streaks to 45' ag.
1424	" "	" "	6 " leakage	"	10	Up all around to 25', in streaks to top on one side	bg alive ag kill in streaks to 15'	Dead to 25'

Continued

1321	Zinc chloride Water to	5 oz 2 qts	2 das.		15	Not in outer 4 rings	bg all killed ag all alive	Dead to 15' ag, in streaks to 20' ag.
1316	" "	10 oz 2 qts	1 da.	Part filled; no pitch	9	In streaks to 3' ag	bg alive ag killed where poison	
1317	" "	" "	2 das	Pitch	15	In streaks to 25'	bg alive; ag partial kill in streaks to 13 ft.	Dead in streaks to 25' ag
1319	" "	" "	10 "		11	Ag in streaks to 38' over tube	bg alive; ag 80% dead 4" strip to 20'	Dead in strip to 32'ag
1320	" "	" "	"	leak	11	bg few inches below tube ag in streaks to 22'	bg) ag) alive	Dead where poison
1359	" "	" "	Only partly taken up, residue in tin		12	bg to 1 ft.; ag in streaks to 18 ft.; not in outer rings.	bg killed in streaks ag killed to 6 ft.; in streaks to 10 ft.	bg alive ag dead where poison
1360	" "	" "	"	Pitch	12	In streaks to 4' ag	bg alive ag killed to 4 ft.	
1361	" "	" "	2 das	Residue in tin	14	1/3 to 1/2 around to 18 ft. ag.	bg alive. ag killed to 8' on one side.	bg alive ag dead where poison
1446	Zinc Chloride Water to	½ oz 10 qts	5 das	Undet.	7	Up outer 3 rings 30 ft. in streaks	bg) ag) alive	Wet
1342	Sodium fluoride Water to	1 oz. 2 qts	1 day		13	In streaks to 20 ft ag.	bg alive; ag kill to 3 ft. in streaks to 4 ft.	Dead to 20 ft. ag; in streaks to 35 ft. ag.
1293	" "	3 oz 2 qts	Only partly absorbed, sediment in can.		17	Up all around to 5 ft. in streaks to 35 ft. ag.	ag killed to 5 ft. on one side.	Dead to 5 ft. ag; in streaks to 35 ft.ag.
1350	" "	5 oz 2 qts	1 da		14	All around to 15' ag; in streaks to 50 ft.	bg 75% kill. ag kill to 15 ft.	bg 90% dead; ag dead to 75'; in streaks to 33' ag
1353	" "	"	1 da	undet.	14	All around to 10 ft. ag. 2/3 around to 60 ft. ag	bg alive ag killed to 8 ft.	Dead to 12 ft. in streaks to top
1354	" "	"	1 da		14	All around to 18 ft. ag.	100% kill to 18 ft.; in streaks to 20 ft.	50% dead bg; dead in streaks to 30' ag; 3/4 dead at 40 ft.

Continued

1349	Sodium fluoride Water to	5 oz 2qts.	1 day		14	Not visible	bg killed; ag killed to 4 ft.; in streaks to 18 ft.	Dead bg; in streaks to 45 ft. ag.
1297	" "	6 oz 2 qts	Precipitate in can.		7	Injection unsuccessful	Alive	Alive
1298	" "	6 oz. 2 qts	Poison only partly dissolved		11	Up a few feet over bore hole	Alive	Alive
1300	" "	7½ oz 2½ qts	"	"	12	2/3 around to 12' ag. in streaks to 18' ag.	bg killed in streaks ag 1/2 around to 12 ft.	
1450	" "	½ oz 10qts	6 das	Undet.	7	Up all around to 16' ag. in streaks to 36' ag	bg alive ag alive	(Wet)
1454	" "	1 oz. 10qts	4 days 2 qts left in tin when tree felled		4	Up first 2 rings to 10 ft. ag, in streaks to 23 ft. ag	alive ?	alive in streaks to 7 ft. ag
1287	Copper sulphate Water to	5 oz 1 qt.	2¼hrs	Undet.	14	Up outer rings to 10' ag, in streaks to 32' ag.	bg alive ag alive	Dead 10 ft. ag.
1291	" "	"	18hrs	Pitch present, nearly all around tree	19	Poor	Alive	
1309	" "	"	2½hrs	Clean	8	Up to 4' ag, in streaks to 40 ft. ag.	Partial kill to 4 ft. ag	
1281	" "	10 oz ~~2qts~~	3d as ~~leak~~		20	In streaks to 56 ft. ag	bg alive, ag killed to 10 ft. where poison	Dead where poison
1283	" "	" "	3½hrs		13	bg in streaks, down one root, ag to 4 ft. in streaks 53 ft.	bg partial kill ag 2/3 around to 6 ft.	Dead 2/3 around to 10'ag; 1/3 dead to 20'
1284	" "	"	16hrs	Wax in cut. Sol. up ½ around tree	13	bg down one main root. ag in streaks to top on one side.	bg alive ag killed to 2'. Few small larvae alive.	Dead where poison
1346	" "	16oz 2qts	16 hrs	Pitch	14	In streaks to 34'ag - not in outer rings	bg alive; ag killed to 4', tiny larvae alive.	Dead in streaks to 15 ft. ag.
1347	" "	"	4 hrs		14	Up all around to 40', in streaks to 58 ft.	bg alive ag killed to 20 ft.	Dead in streaks to top

Continued

1348	Copper sulphate	16oz Water to: 2 qts	3 hrs		14	All around to 3 ft. ag	Adults killed to 3 ft. ag tiny larvae killed to 2 ft. ag	Dead to 20 ft. ag, in streaks to 30 ft.
1295	" "	20 z 2 qts	4hrs		5	In streaks to 21 ft. ag	bg alive ag partial kill to 21 ft.	bg dead ag dead where poison
1306	" "	"	8 hrs		12	All around to 10 ft. ag, two streaks to 41 ft.	50% kill to 3 ft. ag; tiny larvae alive above	
1308	" "	"	8 "		12	In streaks to top	ag partial kill	
1443	" "	"	8 days		8	Up all around to 10 ft. ag: in streaks to 33 ft. ag	ag alive	Dead where poison(Wet)
1444	" "	"	4 "		8	Up all around to 25 ft. in: streaks to 30 ft. ag	ag alive	Dead to 25 ft. ag
1441	" "	5 oz 10qts	5 "		8	Up all around to 10 ft. ag; in streaks to 25 ft. ag.	ag alive	Dead all around to 10 ft. ag.
1442	" "	"	6 "		8	All around to 12 ft. ag; in: ~~streaks to 32 ft. ag~~	ag alive	Dead where poison
1416	" "	10-oz 10qts	8 " (3 qts. left when felled		8	All around to 30 ft. ag; in streaks to 65 ft.	ag alive	Dead to 30' ag.
1417	" "	"	8 days (2 qts. left when tree felled)		8	Up all around to 20 ft. ag: in streaks to 47 ft. ag.	ag alive	Dead where poison(wet)
1273	Potassium cyanide Water to:	3 oz 1 qt	Leak		9		ag killed to 1ft.; in streaks to 25 ft. ag.	
1274	" "	"	Poison only in: half of kerf		9	1/2 around to 10 ft. ag	bg killed to 1 ft. ag killed 1/2 around to 10ft.	
1275	" "	"	Leak		8	ag in streaks to 15 ft.	Killed where poison	
1276	" "	"	1day	pitch	9	All around to 3' ag; in streaks to 15 ft.	bg 50% killed ag killed in streaks to 15'	Dead where poison
1280	" "	"	1 day		8	All around to 25 ft. ag	bg all killed ag killed to 25 ft.	
1279	" "	4½oz 1½qts	leak		20	In streaks to 38 ft. ag.	bg alive ag killed in streaks to 25 ft.	
1278	" "	6 oz 2 qts	1 day		8	In streaks to 15 ft. ag.	bg alive ag killed in streaks to 15 ft.	

Continued

1294	Potassium cynaide Water to	6 oz 2 qts			17	All around to 10 ft. ag; in streaks to 20 ft.	bg all killed ag killed where poison	Dead where poison
1296	" "	"	1 day			On one side to ground; in streaks to 40 ft. ag.	Killed where poison	
1305	" "	"	1 " "		7	Up all around 2 ft. ag; in streaks to 15 ft.	bg dead ag dead where poison	
1310	" "	"	1 " leak		6	bg to ground ag in streaks to 10 ft.	bg 95% killed; ag in streaks to 10 ft.	
1376	" "	½ oz 10 qts	8 days		12	In streaks to 6 ft. ag.	bg 50% kill ag where poison	
1380	" "	"	8 days		7	All around to 4 ft. ag	Kill where poison	Dead where poison
1379	" "	½ oz 2 qts	Only 1 qt. sol. absorbed in 2 days; removed		7	Up 2 ft. ag.	bg killed to 1 ft. ag killed to 2 ft.	Dead where poison
1427	" "	2 oz 10qts	5 days		4	ag to 8 ft.	bg all killed ag killed where poison	Dead where poison(wet)
1428	" "	"	4 "		5	bg to ground ag to 14 ft.	bg kill where poison ag " " "	Dead where poison(wet)
1429	" "	"	5 "		8	to 15' ag; in streaks to 27 ft. ag.	Bg kill where poison ag " " "	" " " "
1325	" "	10-oz 2 qts	1 day		12	in streaks bg; all around to 10' ag; in streaks to 40ft.	bg 50% kill; ag kill to 10 ft.	bg dead; ag dead to 10'; in streaks to 40'
1326	" "	"	leak		12	down all around bg; all around to 12'ag; in streaks to 23' ag.	bg all killed ag killed where poison	Dead where poison
1327	" "	"	3 das		12	all around to 8'ag; in streaks to 21 ft.	bg all killed ag killed where poison	" " "
1328	" "	"	Leak			All around to 10ft. ag; in streaks to 20 ft. ag.	bg alive ag dead to 10 ft.	" " "
1329	" "	"	1 2 das			All around to 8 ft. ag; in streaks ~~to 30' ag~~	bg killed ag killed to 3½'; in streaks to 8 ft.	" " "
1332	" "	"	½ absorbed - leakage		14	[illegible]	bg killed; ag killed to 12 feet.	Dead ag and in streaks to 15 ft.

Continued

1333	Potassium cyanide Water to	10-oz 2qts	Considerable leakage		14	Up allaround to 5 ft. ag; in streaks to 10' ag.	bg killed; ag killed to 3½'. in streaks to 8 ft.	Dead to 5' ag; in streaks to 10 ft.
1335	" "	"	"	"	12	2/3 around to 10 ft. ag	bg 95% killed ag killed where poison	Dead where poison

T A B L E II

INJECTION OF A DYE IN INFESTED TREES

Tree Number	Solutions	Amounts	Absorp. Time	Condition of Kerf	Days Treat. Final Exam.	Distribution of Indicator
1456	Light green Water	10 qts.	4 days		4	Up outer 5 rings 10 ft.; in streaks to 20 ft. ag.
1457	" "	"	4 days		4	Up outer rings 3 ft. ag; in streaks to 24 ft. in 5th & 8th rings.
1458	" "	"	4 "	Pitch	4	Up outer 2 rings to 15' ag;in streaks in outer 2 rings to 25' ag.
1459	" "	2 qts.	1 "		4	Small streaks in 2nd to 10th ring to 10' ag; streaks to 20' ag, not around beetle galleries.
1460	" "	"	1 "		4	All around in outer 10 rings to 10 ft. ag; in streaks to 25' ag; not around beetle galleries.
1461	" "	"	Sel. down slightly then up only 1/5 around.		4	On two 1-inch streaks in outer 2 rings to 10 ft. ag; not around beetle galleries.

TABLE III

INJECTION OF A DYE IN NORMAL TREES

Tree Number	Solutions	Amounts	Absorp. Time	Condition of Kerf	Days Treat. Final Exam.	Distribution of Indicator
1453	Light green Water	2 qts.	½ absorbed after 5 days; necessary on ½ of tree.	2 injections Pitch in part of cut	6	In streaks 2/3 around to 20 ft. ag. a few streaks to 40' (within 11 ft. of top)
1462	" "	"	1/2 absorbed after 1 day when felled			In first 4 rings to 3 ft. ag. in streaks to 11 ft. ag.
1463	" "	"	Only 1 pt. absorbed when felled 2 days later			In streaks to 4 ft. ag.
1464	" "	"	"	"	"	In streaks to 1½ ft. ag.

TABLE IV

INJECTION OF INFESTED WESTERN WHITE PINES

Tree Number	Solution	Amounts	Absorp. Time	Condition of Kerf	Days Treat.: Final Exam.	Distribution of Indicator	Effect on Brood
1466	Sodium arsenate Water to	1/2 lb. 2 qts.	4 days		35	bg in streaks to ground, below 1ft. not in outer 7 rings ag up outer ring in streaks to top.	100% killed full infested length except few parent adult beetles, no eggs hatched.
1470	Sodium arsenite Water to	2 lbs. 12 qts.	12 " (about)		35	ag in streaks to 10 ft.	95% killed to 10 ft.- brood emerged above.
1465	Potassium cyanide Water to	1/2 lb. 2 qts.	15 days	Pitch globules floating in tin collar	39	ag up outer rings to 10 ft; IN streaks to 25' ag.	100% kill to 10' ag; in streaks to 25'.Rest of tree brood living
1467	Pot. cyanide Water to	2 lbs. 2 qts.	1 day		39	ag up outer rings to 40 ft; in streaks to 60 ft.	bg 50% kill; ag 100% kill to 40'; in streaks to 60 ft.
1468	Sodium fluoride Water to	1 lb. 3 qts.	$1\frac{1}{2}$ "	Poison in bottom of collar (only 3% soluble according to Mr. Bateman.)	37	ag up outer rings to 40 ft; in streaks to 90 ft. ag.	Poor brood from 80 to 140' ag.
1469	" "	1/4 lb. 2 qts.	2 days	Clean	37	Up outer rings to 30' ag; in streaks to 60' ag.	95% kill to 40' ag; 70% kill to 41-60' ag; very little effect above.
1471 Normal tree	Light green Water to	1/2 gram 2 qts.	2 "		35	Up outer 2 rings in streaks to 80 ft. ag.	

ag - above girdle

bg - below girdle

T A B L E V

POISONED, INFESTED, LODGEPOLE PINE TREES (Group II)

	Abs. Time	Days: Treat. to Final Ex.	Inf. Length	Effect on Brood	Effect on Phloem	Effect on Crown
).	22 hrs	35	31'	Eggs killed to 31'. Parent adults (P.a.) alive. (Black fungus in lethal area)	Dead to tip, 56'	Top: sorrel. Base: red.
	"	"	32'	Eggs killed to 20', in streaks to 32'. P.a. alive.	" " " 62'	Top: fading. Base: red.
	5 das	"	25'	Killed in streak to 25'. (Black fungus present)	" " " 70'	Top: green. Base: sorrel.
.	22 hrs	"	26'	Killed in streak to 26'	" in streaks to 74'	All red.
	5 das	"	40'	Killed as eggs and tiny larvae to 40'. Only few P.a. alive. (Fungus present)	Dead to tip, 63'	Top: fading. Base: red.
	"	"	34'	Killed as eggs and tiny larvae to 34'	" " " 67'	" "
.	4 das	37	30'	Killed in streaks to 18'	Dead in streaks to tip (70')	Top: green. Base: red.
	1 day	"	20'	Killed in streaks to 20'	Dead in streaks to tip, 53'.	" "
s	5 das	35	25'	All killed. (Black fungus present)	Dead and stained to tip, 60'.	Top: fading. Base: red.
s	20 hrs	42	20'	Killed as eggs and tiny larvae. Few P.a. alive above 15'	Dead to tip, 72'	Top: green. Base: sorrel.
.	Unsuc. inj.	"	20'	(Very little solution absorbed, tube full of pitch) Very little control.	Only partially.	Top: green. Base: red.
	"	"	38'	" " " "	" " "	" "

TABLE V

Abs. Time	Days Treat. to Final Ex.	Inf. Length	Effect on Brood	Effect on Phloem	Effect on Crown
7 das	32	30'	None	None	None, all green.
Unsuc. inj.	38	35'	(Very little solution absorbed, tube full of pitch and sediment). None	None	" " "
"	"	21'	" " " "	" " "	" " "
"	"	41'	(Only partially effective a short distance)		" " "
5 das	32	30'	Killed in streaks to 15'.	Dead in streaks to tip, 60'.	All green.
8 "	33	30'	Killed to 10', in streaks to 25'.	Dead in streaks to tip, 55'.	Top: fading. Base: green.
4 "	33	32'	Killed to 12', except in a narrow strip, P.a. alive.	Dead in streaks to 45', (not to tip.)	All green.
6 "	"	22'	Killed in streaks to 12'.	Dead in streaks to 20', (not to tip)	" "
2 hrs	44	30'	Killed in streaks to 25'.	Dead in streaks to 30', (not to tip)	" "
19 hrs or less	39	51'	Killed to 10', in streaks to 25'.	Dead to 30', in streaks to tip, 75'	Top: fading. Base: green.
"	"	33'	Killed in streaks to 30'.	Dead in streaks to 40', (not to tip).	All green

TABLE V

Abs. Time	Days Treat. to Final Ex.	Inf. Length	Effect on Brood	Effect on Phloem	Effect on Crown
9 das	37	29'	None	None	None, all green.
5 "	35	30'	Killed on one side to 6'.	Dead in streaks to 10'	Top: red. Base: green.
"	"	30'	None	Dead to 14'.	All green.
6 "	37	20'	Killed to 5'.	Dead to 6', in streaks above.	" "
6 "	37	30'	Killed to 6'.	Dead to 10', in streaks to 25'	" "
4 "	33	18'	All killed.	Dead in streaks to 30'.	" "
5 "	"	30'	Killed in streaks to 12'.	" " " "	" "
19 hrs	55	28'	All killed. (Attack all on one side).	Dead to tip. (On infested side).	" "
" "	40	33'	Killed P.a., eggs and tiny larvae to 6'.	Dead to 6'.	" "
18 hrs	"	20'	All killed.	Dead in streaks to 45'.	" "
24 hrs	"	15'	" "	Dead in strip to 40'.	" "